Chapter 10
Test Fill Construction

10-1. Foundation Preparation

The proper preparation of the foundation for a test fill is of special importance since settlement readings on the surface of the lifts rather than in situ density tests are commonly used to evaluate the relative compaction obtained. Fortunately, in areas near quarry sites, rock foundations can usually be provided with a minimum of overburden stripping. If, however, the foundation consists of soil or weathered rock, it must be thoroughly compacted prior to fill placement, preferably until no further significant settlement can be observed. Although undesirable, where further consolidation of a compressible foundation under fill loads is possible, settlement plates should be installed in the foundation to provide data needed to correct the test fill settlement readings. If foundation settlement plates are needed, the considerations of test-fill layout should include the feasibility of locating those plates between and about test lanes in a manner which would allow sufficiently accurate determination of average foundation settlement and avoid the obstructions of plate risers in the placement and rolling of the fill. Guidance concerning use of settlement plates (see Figure 10-1) is provided in EM 1110-2-1908. A thoroughly compacted rock pad (or leveling course), 61 to 91 cm (2 to 3 ft) thick, should be placed on the foundation (whether soil or rock) prior to placing the first test lift in order to ensure that all foundation depressions and undulations are filled and a level surface is obtained. Material for the pad can be either the same rock to be used in the fill or waste rock obtained from the test quarry prior to exposing that considered to be representative of the rock to be placed in the project embankment. Placement of the pad should be in at least two lifts with rolling applied until negligible settlements are observed from level readings made on its surface.

10-2. Placement of Hard to Medium Rock

In the infancy of the transition from dumped to compacted rockfill beginning in the mid-1950's, several different methods were used to dump and spread the rock. In addition, different ideas relative to the maximum rock size which should be allowed compared with lift thickness were also evident (Sherard and Cooke 1987). In the last 15 years, the considerable experience gained in construction and performance of compacted rockfill dams has resulted in general agreement on these practices for hard to medium rock (Sherard and Cooke 1987) as discussed below.

a. The preferred method. The preferred method for rockfill placement is to dump on the surface of the layer being placed and then to spread the layer to the desired thickness with a crawler tractor by pushing the material over the advancing face of the lift as shown in Figures 10-2 and 10-3. This procedure creates significant segregation with the larger rocks in the bottom of the lift and the smaller rock and fines in the upper part. The main advantage of this technique derives from the relatively smooth upper surface resulting from pushing the dumped rock a short distance on top of each layer being placed such that depressions and voids between larger rocks become progressively filled with small rocks and fines. This approach also facilitates maintaining the desired lift thickness because the dozer operator is always advancing the lift ahead upon the smooth surface at its proper elevation. The smooth layer also reduces tire wear, allows higher truck speeds, and provides a better surface upon which to operate the vibrating roller.

b. Contrast with past practice. Earlier rockfill placement practice attempted to avoid segregation of the rock and/or generation of fines on the lift surface to form as homogeneous a compacted mass as practicable. The procedure was to dump the truck loads of rock in piles spaced upon the surface of the previously compacted lift and then to spread the piles to form the desired lift thickness. A very irregular fresh fill surface is created which makes equipment travel difficult, rapidly wears the rubber tires, and subjects vibratory rollers to damage because they do not withstand continuous operation on irregular surfaces where the drum is pounding on a few high points of hard rock. This method of rockfill placement is now considered obsolete by most specialists (Sherard and Cooke 1987), but is still occasionally proposed.

c. Stratified rockfill is preferred (Sherard and Cooke 1987). Past practitioners viewed the generation of stratified rockfill in the placement and compaction operations to yield undesirable properties with respect to permeability and compressibility. Considerable experience with the performance of rockfill dams, whether earth-core or concrete-faced, has shown that there are no technical disadvantages to the preferred method of placement in segregated layers. Sound rock derives its typically adequate shear strength from a combination of the density of the upper-lift zone of finer particles and the larger particle wedging and interlocking in the lower-lift zone rather than strictly from density. The stratification also assures that

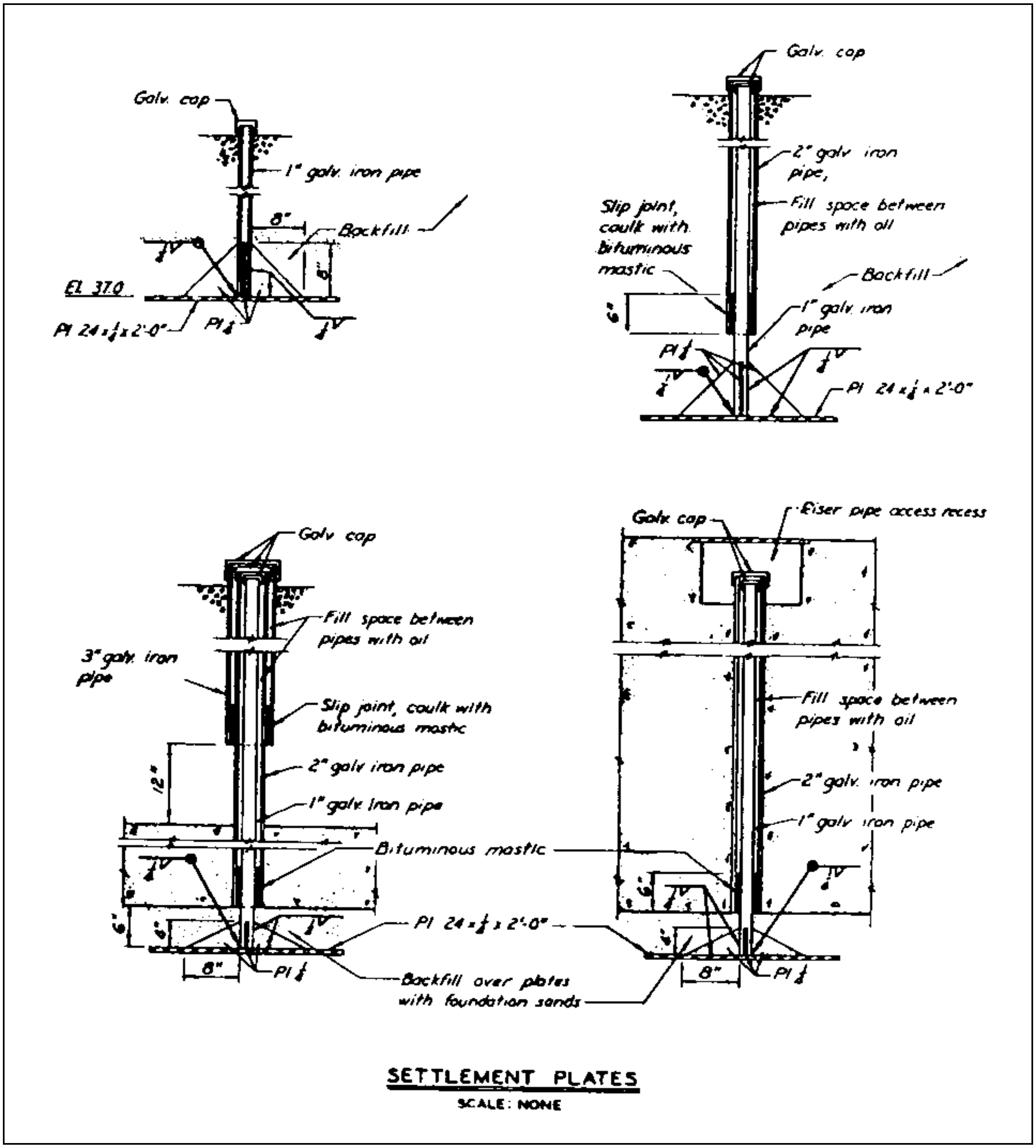

Figure 10-1. Typical settlement plates (from EM 1110-2-1908, Part 2)

any flow through the embankment will move much more easily in the horizontal direction than in the vertical which offers downstream slope stability advantages during construction for a concrete-faced dam if an upstream pool is impounded during construction or if there is an overtopping allowance during construction. Even for rockfill containing considerable fines, the stratified structure results in a greater average permeability compared with fill placed to a more homogeneous character.

d. Lift thickness. Lift thicknesses employed in more recent times for medium to hard rock have averaged about 1 m (3.3 ft). Cooke (1990) states that the 9.1-Mg

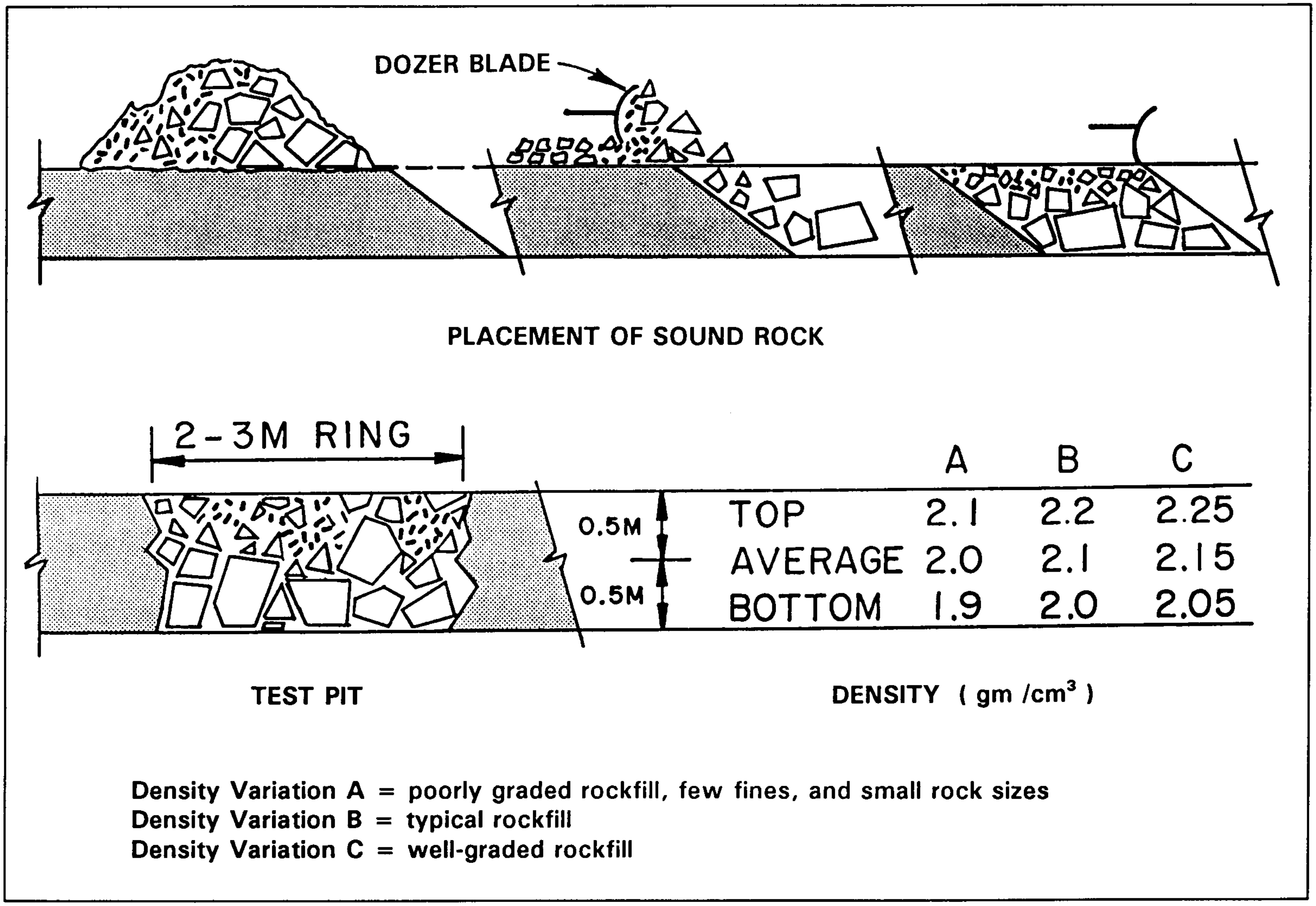

Figure 10-2. Placement of sound rockfill and resulting density variation (after Cooke 1990)

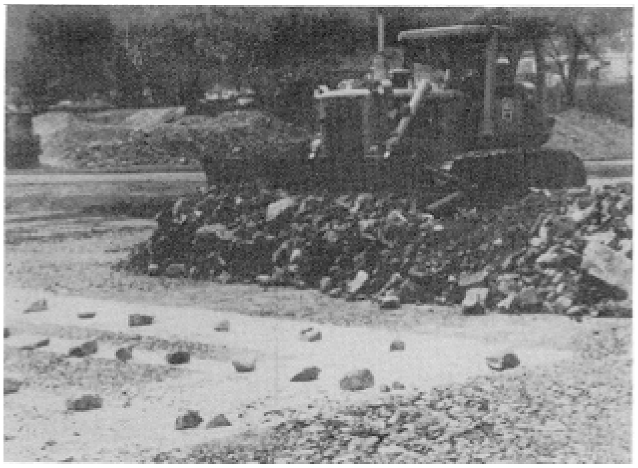

Figure 10-3. Placing a lift in the Cerrillos Dam test fill (Note the marking of the previous lift surface with plastic strips and lime)

(10-ton) vibratory roller (Figure 10-4) has generally provided excellent results for this thickness. Experience suggests that selection of lift thickness for sound rock up to about 1 m (3.3 ft.) is not a particularly critical item with respect to ability to achieve adequate compaction but can be based on quarry-run rock size brought to within the range of lift thicknesses stated above. However, the use of lift thicknesses approaching or exceeding 1 m should be on the basis of justification derived from the test fill. The literature clearly agrees that for sound rock, quarry-run material can usually be produced to be satisfactory.

Figure 10-4. A 9.1 mg (10-ton) vibratory roller at work on the Cerrillos Dam test fill

e. Maximum particle size versus lift thickness. It has been customary to limit the maximum particle size to something less than the loose-lift thickness (say, a maximum of 0.9). However, it has been clearly established that maximum particle size equal to the lift thickness is acceptable. With the preferred placement practice, the vibratory roller will seat these particles among the smaller rocks and fines. The presence of particles equal in size to the lift thickness has not been found to result in unacceptably poor compaction of intervening material, i.e., any detrimental effects on the compaction or the compressibility of the fill.

f. Grading. Sound rock is highly segregated in each lift such that grading of the quarry-run rock is not important. Cooke (1990) points out that for a given roller, well-graded quarry-run sound rock will give the highest density and modulus (lowest compressibility), but all quarry-run rock, even when poorly graded, has been satisfactory with respect to embankment performance. He further states that if the rock is hard, a satisfactory general specification is "quarry-run rock - the maximum size shall be that which can be incorporated in the layer and provides a relatively smooth surface for compaction, not more than 50 percent shall pass a 2.5-cm (1-in.) sieve, and not more than 6 percent shall be clay-sized fines." Natural gravels with sound particles do not conform to the typical definition of rockfill but may be considered for use in the shell of a dam. Loose lift thicknesses for gravels have ranged between 0.3 and 0.9 m (1 to 3 ft.) depending on particle size and percentage of minus U.S. Standard No. 200 sieve sizes (Cooke 1984).

10-3. Placement of Soft Rock

Dumped rockfill, which is still used in downstream portion of sloping-earth-core dams or in the shells of central earth-core dams, requires sound rock meeting concrete aggregate specifications. However, very low compressive strength rock such as possible in siltstones, sandstones, shists, argillite, and other potentially weak rocks may also be used as compacted rockfill. This is one of the cost advantages gained from compacted rockfill as compared with dumped rockfill in that weak rock formerly wasted from quarries for dumped rockfill dams became acceptable materials for even very high compacted embankments.

a. The preferred method. Soft (weak) rock which arrives at the test fill containing appreciable fines or which breaks down significantly in the placement operations derives its shear strength from density so that it is generally dumped and spread by crawler tractor directly on the preceding lift to minimize segregation and yield a more compact mass. An exception would apply in cases where the breakage under the crawler tractor alters the fill from proper classification as rockfill into a soil material and alternative methods offer the possibility of retaining satisfactory rockfill traits. This statement assumes that the determination has been made that the marginal material placed in a manner retaining rockfill traits will not deteriorate into a soil material under embankment stresses or environmental factors.

b. Lift thickness. Because fill composed of soft, weaker rocks and appreciable fines derives its satisfactory properties from density, test fill results are likely to show that thinner lifts (compared with hard, durable rock) on the order of 0.46 to 0.6 m (18 in. to 2 ft) are required along with an increase in the number of passes of the roller from, say, usually 4 for hard rock to 6 or 8 for the softer, weaker rock. Some breakdown may be desirable to achieve the desired strength for these materials. The compacted mass should not exhibit any voids among larger particles, i.e., the larger particles should be consistently surrounded by finer material which has clearly been densified by the compactive effort between and among the larger particles. The use of water (to be discussed below) in the compaction of soft rock may result in the test-fill finding that somewhat thicker lifts can be used.

c. Maximum particle size. Maximum rock size may be equal to the lift thickness but these sizes will typically break down during placement and compaction.

d. Grading. Grading of weak rockfill materials is of no consequence since the procedures, i.e., lift thickness, compaction, and use of water (to be discussed below) are adopted to produce some breakdown and high density.

10-4. Rockfill Versus Soil

Weak rock introduces the possibility that it will break down during placement and compaction such that desirable shear strength and compressibility cannot be achieved unless it is compacted with water content and density control using rollers typically employed for soils. In some cases, the determination that materials will degrade to such an extent (whether by quarrying, hauling, placement, and compaction or as the result of environmental factors such as wetting or air exposure) can be made on the basis of previous experience, tests on core samples, or experience gained in the test quarry rather than resulting from test fill observations. Otherwise, a test fill may be the only way to make the determination. It is sometimes possible to maintain the rockfill character of the material through avoidance of excessive breakage in the fill operations by processing the quarry-run material to remove fines and smaller sizes, by using rubber-tired equipment for the spreading operation, by adjusting roller passes, weight, or vibration settings, or by a combination of these. If excessive fines exist in the materials or if they are generated during compaction, the vibratory roller may be less effective in compaction compared with the 45.4-Mg (50-ton) or 68.0 Mg (75-ton) pneumatic roller. In general, materials which retain the properties to be properly called rockfill can be brought to satisfactory density using a vibratory roller. Superior compaction by a pneumatic roller would probably indicate that the material is more properly classified as a soil and should be treated as such in design, construction, and construction control. Perhaps the key concept distinguishing rockfill from that of soil is that the rock particles are in contact within the compacted mass as opposed to “floating” in a “matrix” or “binder” of soil-sized material (i.e., sands to silts or clays).

10-5. Use of Water

The use of water in compaction of rockfill (Figure 10-5) is beneficial no matter what the rock quality, but becomes especially important for types of rocks which exhibit strength loss upon wetting (usually indicated by low compressive strength) or whenever there is an appreciable presence of fines. The use of water in the compaction of weak rock, whether or not some breakdown is a desirable end, has been general practice. Indeed, one of the additional indicators as to whether or not the soft-rock material retains rockfill properties, is whether or not the rockfill is strong enough to support hauling equipment and the vibratory roller when wetted to saturation. If the equipment becomes immobile, the material ruts more than several inches under the tires of the trucks, or the added water stands upon the surface, the material has soil strength, not rockfill strength. This observational approach is valid also for hard and medium rock if excessive fines are present. The application of water has been on the order of 15 to 20 percent of the volume of the material. The use of water may represent a serious environmental factor if drainage from the fill creates turbidity pollution of the stream or river. Where water use is restricted for environmental or economic reasons, Cooke (1984) cites alternative practice of placement of weak rock in thinner lifts of 0.6 m (2 ft) or less along with an increase in the number of passes of the vibratory roller. For any weak rock which exhibits a significant loss of

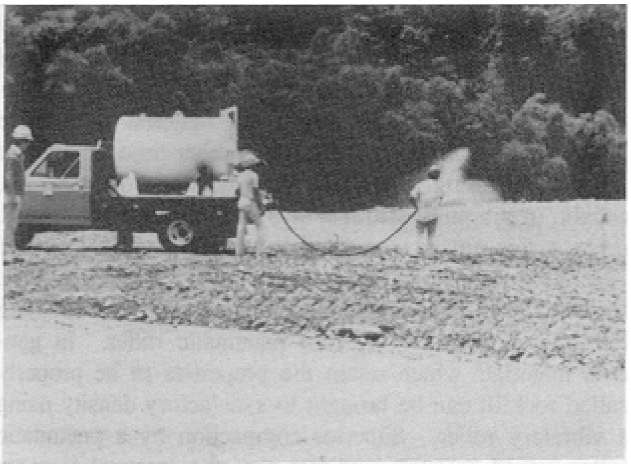

Figure 10-5. Applying water prior to lift compaction on one of the Cerrillos Dam test fills containing appreciable fines (Note: The operation shown above was an expedient method for the test fill at the Puerto Rico damsite. More typically, water is applied from a pressurized tanker truck with a rear spray bar)

strength for saturated specimens, a saturated test fill should be conducted to establish placement and compaction specifications.

10-6. Compaction and Compaction Equipment

After the rock has been placed in the desired lift thickness, the compaction operation is begun. Where surface settlement readings are to be used to assess densification (the typical practice), it is advantageous to smooth the surface of the lift for marking of the settlement grid by making one complete coverage with the vibratory roller with the vibrating unit off. The procedure for settlement readings is addressed in Chapter 11. As has been previously stated, it is important that the compaction operation be accomplished in a manner to simulate anticipated project procedures, except for interruptions required to make measurements and observations. Each pass of the roller, whether vibratory or rubber-tired pneumatic, should overlap the previous pass by about 0.3 m (1 ft). Specifics regarding the vibratory and pneumatic roller are discussed in the following paragraphs.

a. Vibratory roller. Vibratory rollers (Figure 10-4 and Appendix B) have evolved considerably since their inception in the mid-1950's. It is important for test-fill designers and field personnel to become familiar with current manufacturers' literature and recommendations for operational speed versus frequency settings to obtain the most efficient compaction. Appendix B contains recent information obtained by Los Angeles District pertaining to these parameters and the specifications they instituted for Seven Oaks Dam. The amplitude of the roller is the distance the drum lifts off the ground in its vertical vibration and the frequency is the number of times per minute it lifts off the ground (i.e., number of impacts) expressed as vibrations per minute or VPM. Numerous studies on distance between successive impact points and centrifugal force have been conducted over the last 20 years which have resulted in the establishment of 6 to 8 impacts of the drum per lineal foot of travel as a minimum for optimal performance. Appendix B presents a table of VPM versus impacts per lineal foot for different speeds of operation of the roller. A modern roller can operate at a frequency of 1500 to 1800 VPM delivering forces in excess of 4.1 Mg (9,000 lb) per 0.3 m (1 ft.) of drum width. Increased frequency translates to increased speeds of operation which represents construction cost savings. With increased frequency, a greater force is applied and more impacts per lineal foot of rolling can take place. As part of the test fill evaluation objectives, these variables can be adjusted to provide the optimum rolling procedures for the given material and offer some latitude to alter the degree of breakdown if it is a problem.

b. Pneumatic roller. Bertram (1973) suggests specifications for a 45.4-Mg (50-ton) rubber-tired roller as follows: "Pneumatic rollers shall have a minimum of four wheels equipped with pneumatic tires. The tires shall be of such size and ply as can be maintained at tire pressures between 552 kPa and 690 kPa (80 and 100 psi) for a 11.3-Mg (25,000-lb) wheel load during rolling operations. The roller wheels shall be located abreast and shall be designed so that each wheel will carry approximately equal load in traversing uneven ground. The spacing of the wheels shall be such that the distance between the nearest edges of adjacent tires will not be greater than 50 percent of the width of a single tire at the operating pressure for a 11.3-Mg (25,000-lb) wheel load. The equipment shall be subject to the approval of the contracting officer." Pneumatic rollers should be towed or operated at speeds less than 8 kmph (5 mph). Heavier pneumatic rollers are now available and should be considered as applicable but documentation of their use on rock test fills has not been discovered. For most test fills, the optimum performance of either a pneumatic or vibratory roller has been achieved in 8 passes or less. Typically, the compaction program for any given lift thickness has been to schedule a maximum of 8 passes (lift coverages) with interruptions between each two passes for measurements and observations. After compaction of a given lift has been completed and all tests and measurements have been made, the surface of the completed lift may be covered with a marker material such as lime or a heavy plastic membrane (0.02 cm or 8 mil maximum thickness) as shown in Figure 10-3 to facilitate identification of individual lifts within an inspection trench or pit after the entire test fill is complete. Inspection trenches or pits will be discussed in Chapter 11.